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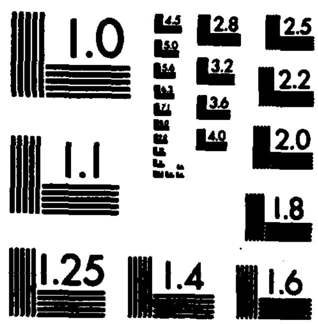

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USAF EXPERIENCE IN AIRCRAFT ACCIDENT SURVIVABILITY

by

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INTRODUCTION

Good afternoon, gentlemen. As you know, safety of flight has improved tremendously over the past half century. The Air Force major accident rate has declined from 281 in 1924 to 2.9 in 1974, while the fatality rate has dropped from 35 to 2.6. Since it is unlikely we can ever insure a zero accident rate, we must provide for some survival potential when the inevitable event, the crash, occurs. I fully understand that the degree of crashworthy features we install in an aircraft must be commensurate with the hazard presented. To make an aircraft completely crashworthy would be enormously expensive, both in acquisition cost and weight penalty. However, when we analyze previous accidents, and identify those crashworthy deficiencies which generated the most casualties, certain improvements become quite apparent.

HAZARDS DURING AIRCRAFT ACCIDENTS

Before going further into the Air Force experience in accident survivability, let me briefly touch on the predominant hazards which occur during the crash sequence.

There are ~~only~~ two basic considerations, ~~we must address~~. First is the exposure to dynamic forces during the deceleration phase. These are the forces imparted on the crew member or passenger by his restraint system, by collapsing → dele

cabin or seat structure, by inadequately or unrestrained cargo, or by the member's body impacting surrounding structural components. In high velocity crashes, these dynamic forces are usually so severe that survival is not possible. However, in many crash events, especially during takeoff and landing phases of flight, these dynamic forces are rather moderate. Injuries produced during the dynamic deceleration process should be minimal if the aircraft is properly designed for crashworthiness.

Second is the hazards of the post-crash environment. Predominant among these post-crash hazards is, ~~of course~~, fire. If the aircraft comes to rest in water, there is the additional possibility of drowning. However, for the most part, fire is the primary concern. With the flammables we have on board the aircraft--hydraulic fluids, jet fuel, lubricating oil, and so forth--fire during or after the dynamic phase of the crash is almost certain.

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Rapid onset of fire can be disastrous, but the lethal conditions that accompany the fire are not limited to heat and incineration. Smoke created by burning cabin interiors rapidly, within seconds, reduces visibility, thus complicating egress. Pyrolysis of nonmetallic cabin interiors produces noxious by-products which can be just as lethal as the fire. Combining these with panic, the inability to locate an escape portal, and failure to operate the

emergency door when found, all add up to a pretty grim situation. Exactly how much time is available to get out once the fire has started varies with the magnitude of the fire.

I believe it is safe to assume that you would have no more than 90 seconds to make a successful egress under optimum circumstances. More realistically, the time available is more like 30 to 60 seconds after ignition. If the individual is not out of the aircraft in this very short time frame, all the fire-fighting resources the base can muster will be of little use.

In some accidents, the onset of fire is so rapid that a lethal thermal and toxic environment is produced in less than 10 seconds. In such instances, survival is unlikely without automatic fire suppression systems.

In analyzing the pyrolytic by-products of some of the materials currently installed in cargo aircraft, we find the following: volumes of carbon monoxide and carbon dioxide, and some quantities of sulphur dioxide, hydrogen fluoride, chlorine, hydrogen cyanide, and phosgene. These substances, working alone or in conjunction with one another, can prove to be very unhealthy very fast.

CASUALTIES PRODUCED IN SURVIVABLE CRASHES

Now that I have touched on some of the hazards that can be expected during a crash event, let me relate these hazards with their importance in producing injuries.

I scrutinized a total of 121 major transport aircraft accidents from 1967 through 1974 in which there was at least one injury. This is the way these accidents shredded out. Of the 121 accidents, 62 were what I term survivable, i.e., at least one or more of the occupants did survive, or his death could have been prevented. In the 121 total accidents, 1,385 aircrew and passengers were involved, of which there were 891 fatalities, 154 major injuries, and 72 minor injuries. Looking at the 62 survivable accidents alone, there were 718 occupants involved, of which 226 were killed, 151 received major injuries, and 72 received minor injuries.

When evaluating the injuries sustained in these survivable accidents, we find that mortal injury could have been prevented in 185 of the deaths had the aircraft provided better crashworthy features. Also, 134 of the 151 major injuries and 69 of the 72 minor injuries would have been prevented or minimized through application of crashworthy hardware and techniques. Many of the major injuries which I labeled nonpreventable were those incurred because the individual was not restrained, either because his duties required his mobility or because there was a disregard for discipline.

An appraisal of the "hows and whys" these casualties occurred is important when determining the major crashworthy problems in our transport fleet. I have developed

these data for the USAF transport fleet as a whole and for the existing cargo aircraft which are performing missions similar to that projected for the advanced medium short takeoff and landing (STOL) transport (AMST). These aircraft are the C-7, C-123, and C-130. All statistics represent actual transport accident experiences from 1967 through 1974.

This slide depicts the injury distribution by percent of major injuries sustained in these accidents. The significant feature of this graph is the very large proportion of injuries attributed to burns. Many of these burn injuries were due to lack of protective clothing. Nevertheless, this injury cause would have been greatly reduced if the onset of fire had been delayed.

A breakdown of injuries caused just by dynamic deceleration forces reveals that most of these were sustained by the head and legs, especially in the STOL-type aircraft. These injuries to the head and extremities would most likely be due to flailing or seat collapse, whereas the back injuries were caused by poor crashworthy seat and restraint design.

Looking at the causes of these dynamic injuries, the real bad actors are as expected: flailing and seat failure. Failure of restraint systems, both for cargo and personnel, accounts for only about one-fourth the major injuries in

the STOL-type aircraft. Methods to reduce injury due to flailing and seat failure must include delethalization of the aircraft interior surfaces and incorporation of adequate crashworthy seat design during initial procurement of the system.

Up to now, we have concentrated on injury alone. One of the very important considerations in accident evaluation is why people are unable to survive. In many accidents the impact forces are so great that survival potential is nil. However, in survivable accidents the situation is quite different. Let's take a close look at the cause of death for those aircraft accident fatalities that should have survived. This slide breaks down the primary cause of death in four categories; burns and asphyxiation, asphyxiation, drowning, and dynamic injury. Many accident reports fail to distinguish between death by burns and those by asphyxiation; therefore, the category burns/asphyxiation may include many deaths from asphyxiation in which the body later burned. The asphyxiation only category includes deaths positively attributed to asphyxiation. The first three categories all relate to death because the individual, although he survived the initial deceleration forces, failed to make a timely egress from the aircraft after the motion had stopped. These three categories are combined in the last column. As you can see, in the STOL-type

aircraft, 93 percent of the fatalities might have been prevented if the individual had been protected from post-crash factors.

The exact reason why people failed to get out of the aircraft is very difficult to determine when considering current accident investigation methods. However, after a detailed analysis of survivable accident reports, along with some subjective interpretation, certain trends were identifiable. These influencing factors are shown here as a percentage of the preventable deaths for which they were partially responsible. As can be seen, injury impairment ranks rather low, whereas confusion, blocked egress, and fire are much more prominent.

To tie this all together, I have this final accident distribution chart which takes into account both fatalities and injuries, along with their primary cause. For the STOL-type aircraft, about three-fourths of these casualties are caused by exposure to post-crash factors. Obviously, this is where we should concentrate our efforts.

SURVIVABLE ACCIDENT CASE HISTORIES

Speaking in terms of cold statistics often does not reflect the tragic events which accompany these survivable accidents. When we examine the occupants' unsuccessful attempts to survive, the need to improve crashworthiness

in these aircraft becomes obvious and essential. I would now like to describe several accidents which vividly illustrate what I mean.

A KC-135 stalled and crashed on takeoff, with 13 souls on board. Although moderate impact forces were experienced, none of the occupants suffered disabling injuries. The rapid onset of fire and smoke prevented 12 of 13 from getting out of the wreckage. All 12 died of asphyxiation. The 13th did get out, but died later from pulmonary complications and burns. Review of the accident report revealed that occupants of the cabin had all attempted to escape but the rapid onset of fire and the build-up of smoke prevented successful egress.

Another KC-135 crashed during a 3-engine landing attempt. The aircraft impacted slightly short and then slid up onto the runway. The casualty distribution was 11 dead, 11 major, 3 minor, and 31 with no injuries. In an attempt to clear an embankment, the pilot applied full elevator, which caused the aircraft to touch down on the boom pod. This damaged the aft fuel tanks, resulting in fire in the rear passenger cabin. This generated considerable panic among the passengers. Many people got out of their seats after the second impact and were thrown to the floor on the third and final impact. Although the aft emergency exit was opened before the plane came to a stop, only three people used it.

Looking at the location of bodies, four people were found next to the left overwing hatch. Some shifting cargo had impaired their egress long enough for them to be incapacitated by smoke. The remainder of the bodies were in the aft section among the airline-type seats.

The need for additional escape portals in this aircraft is quite apparent.

Another accident which really resulted in tragic consequences involved a C-130 that aborted on takeoff and came to rest over an embankment. There were 35 fatalities, three with major injuries, and 18 with no injuries. The impact forces were very light and, in themselves, caused no injuries. After the aircraft stopped, the passengers all surged toward the crew entrance door and paratroop doors. The forward crew door was jammed shut, halfway into mud, and the crush of passengers prevented the paratroop doors from being opened. All 35 passenger deaths were from suffocation and/or subsequent burns; however, some of the asphyxiated bodies were not even burned. All of the fatalities were found near these two exits, even though others were available. Again panic, confusion, and insufficient lighting contributed to the demise of these individuals.

Throughout these examples I'm sure you have recognized disastrous results of post-crash factors on casualty occurrence. Failure to make a rapid escape usually proves fatal.

In many cases, egress is delayed because the occupant is not familiar with the emergency egress system, but not in all. We have two accidents on record--a C-47 and a KC-135--where experienced crew members in the cabin area survived the dynamic impact forces without major injury but were unable to open the escape portals before being overcome by smoke. In both cases, there was positive evidence that the door opening sequence had been initiated, but, unfortunately, the individual just ran out of time.

PROPOSED CRASHWORTHY IMPROVEMENTS

Now that we have examined how casualties are gene: during aircraft accidents, it may be well to review some proposed methods to reduce injury and death. The proposals are in varying degrees of development and all appear to have practical application.

Since failure to make a timely egress has figured prominently in casualty generation, providing an exit automatically on impact would go far in improving survival potential. A system designated ELSIE, which stands for Emergency Life Saving Instant Exit, has been developed by the Air Force. It provides escape portals by detonating a shaped charge around a specially designed fuselage panel. Based on the statistics compiled from my review, it is estimated that this feature alone would have definitely saved about 45

percent of the avoidable deaths occurring in the C-7, C-123, and C-130 aircraft. These were the deaths confirmed as asphyxiation. If we include those that died of burns/asphyxiation, this figure rises to about 80 percent. ELSIE has been successfully tested on a static mock-up and has been installed on C-131 aircraft for operational testing.

Numerous studies and reports have stressed the need to reduce the occurrence of post-crash fire or retard its onset. The statistics I have cited certainly support this requirement. There have been proposals for fire containment, i.e., use of gelled aircraft fuels and installation of self-sealing or honeycomb fuel tanks. These improvements might be considered in future designs. Another approach to reduce the hazards of post-crash fire is the use of lower volatility jet fuel. This possibility is now under active Air Force consideration and should have a very beneficial impact on crashworthiness.

We are currently evaluating fabrics and materials to determine their fire-resistant characteristics. This evaluation, being accomplished under contract, will identify the most suitable materials, not only from the standpoint of flame-resistant qualities, but also of their potential to produce toxic pyrolytic by-products. Adherence to recommendations of this effort will help to reduce the lethal toxic/thermal environment following impact.

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Another method to combat post-crash fire is to install fire-suppression systems in the occupied area. It is expected that such a system would provide approximately 120 seconds of escape time. This would greatly reduce both injury and death following the crash. A good candidate is the Halon 1301 fire-suppression system. This suppressant is a relatively nontoxic substance and has rapid fire-extinguishing features. Also, the cost of such a system does not appear to be prohibitive. How such a system would respond following a crash in which large volumes of flammables are present is not known. However, enough evidence on its potential is available to warrant further consideration.

There is a definite need to improve emergency lighting. In a previous analysis on transport accidents, not one survivor interviewed considered the post-crash lighting to be adequate. Self-contained, impact-initiated lights, of sufficient intensity level, should be developed which can direct occupants to the nearest usable escape exit. These lights should be located well below the ceiling to avoid being obscured by rising smoke.

Although I have stressed the need to reduce exposure to the post-crash environment, we should not neglect those crashworthy improvements designed to reduce death and injury from dynamic crash forces. This would include improved

seats, restraints, both for occupants and cargo, delethalization, and cabin integrity. However, the number of deaths and injuries directly attributed to deficiencies in these items would suggest that improved egress methods take priority.

CONCLUSION

I believe you will agree that there is much room for improving aircraft crashworthiness. Why then have we not been able to convert many of these crashworthy proposals into hardware? Although there may be many reasons, I think the most prominent is the cost of these features in terms of money and performance. A persuasive argument as to the actual need for improved crashworthiness has not been presented to the aircraft developers and users. In other words, the Air Force crashworthy program has lacked one major ingredient--salesmanship.

When trade-off decisions are made, one of the first elements to be discarded is these newly defined safety requirements. Unless those in charge of aircraft acquisition can be convinced that these features are practical, will not compromise performance capability, are operationally feasible, have low risk development schedules, and show favorable life cycle cost distribution, it is unlikely that they will be accepted. We at the Directorate of Aerospace Safety have established an action team to analyze these

features in this context. We feel that an objective, deliberate evaluation will succeed in producing the convincing argument needed to sell those practical crashworthy features which show promise.